Selected Functional Properties of Flour From Three Sweet Potato (Ipomoea batatas L.) Varieties

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Abstract

The study was conducted to determine, compare and evaluate the selected functional properties of flour from three different varieties of sweet potato, namely, NSIC SP-32, PSB SP-17 and VSP-6 produced by PhilRootcrops, Visayas State University. These properties are necessary for the development and improvement of food products from sweet potato which provide an excellent means of increasing the utilization of this nutritious high-yielding crop. All the flour samples showed great potential in the characteristics (moisture content and pH) for long shelf life. PSB SP-17 flour had the highest potential in the applications for thickening, binding and gelling in food processing compared to the other two flour samples, as supported by the data on water absorption capacity and gelation capacity. PSB SP-17 flour showed good fat-binding ability for applications in meat processing and colloidal food systems. It also showed the highest viscosity and lowest amylose content. NSIC SP-32 flour possessed these characteristics but only came second to PSB SP-17. VSP-6 showed the highest bulk density which is of good use in packaging and food preparations. It also showed the highest foaming capacity compared to NSIC SP-32 and PSB SP-17.

Keywords: Functional properties; sweet potato flour; sweet potato varieties

Introduction

Flour is a fine powder made from cereal or other starch-based produce. In our country, it is a key ingredient in bread production which is considered as a second staple food in the Filipino diet next to rice. Flour is most commonly made from wheat, while flour produced from non-wheat sources such as sweet potato is called composite flour.

Sweet potato (Ipomoea batatas L.) is a nutritious vegetable. It is an excellent source of vitamin A precursor, vitamins and minerals, energy, dietary fiber and some protein. Sweet potato consists of about 70% carbohydrates (dry basis) of which a major portion is starch which can be utilized as a functional ingredient in certain food preparations (Avula, 2005). Philippines is one of the countries in Asia which has the largest amount of land with sweet potato production. In spite of the fact that it is cheaper than other crops, this abundant resource is poorly utilized and sadly neglected as innovations in the food industry.
snack foods, confectionery products, and for alcohol production and in brewing industries in China, Japan, and other Asian countries. Determining of the functional properties of flour from varieties of sweet potato produced in PhilRootcrops at the Visayas State University is necessary for the development of new and improved processed products from sweet potato flour as there is scarcity of data regarding these properties which can provide an excellent means of increasing the utilization of this high-yielding, nutritious crop (Avula, 2005).

Functional properties are the intrinsic or fundamental physicochemical characteristics which determine the application, use, processing and storage of food material for various food products (Adeleke & Odedeji, 2010) like flour. These include solubility, absorption, water retention, frothing ability, elasticity and absorptive capacity for fat and foreign particles. Typical functional properties include emulsification, hydration (water binding), viscosity, foaming, solubility, gelation, cohesion and adhesion. Adequate knowledge of these physicochemical properties indicates the usefulness and acceptability of food products for industrial and consumption purposes. Functional properties reflect the complex interaction between the composition, structure, molecular conformation and physicochemical properties of food components together with the nature of the environment in which these are associated and measured (Chandra & Samsher, 2013). These characteristics are needed for the evaluation, utilization and improvement of products derived from the flour of different sweet potato varieties.

The objective of this study was to determine the functional properties such as swelling power, viscosity, pH, moisture content, emulsification capacity, absorption capacities, foaming capacity, bulk density and gelation capacity of flour derived from three recommended varieties of sweet potato namely: NSIC SP-32, PSB SP-17 and VSP-6; and to evaluate and compare the functional properties of each flour.

**Methodology**

**Sample Collection**

Three types of flour from different processed sweet potato varieties namely: NSIC SP-32, PSB SP-17, and VSP-6 (Fig.1) were purchased from PhilRootcrops, Visayas State University, Baybay City, Leyte. Each type of flour was stored in a zip-locked polyethylene plastic bag at room temperature for the whole duration of the experiment. The sample for each replicate was collected by scooping and by weighing the needed amount from the container. The container was shaken before getting the sample for the next replicate. The same sample collection was practiced for every parameter of the study.

![Sweet potato flour samples](image1.jpg)

*Figure 1. Sweet potato (Ipomoea batatas L.) flour samples used in the study*

**Moisture Content**

Moisture content was determined using the method of Avula (2005). Two grams of each sample was placed into pre-weighed aluminum foil containers. It was placed in an oven and dried at 105°C to constant weight. The % moisture content was computed as follows:

\[
\text{Moisture(%)} = \frac{W_i - W_f}{W_i} \quad (1)
\]
where:

\[ W_f = \text{weight (g) of dried sample} \]
\[ W_i = \text{weight (g) of initial sample} \]

**pH**

Ten grams of each sample was homogenized in 50 mL of distilled water using the Imarflex IB-350P blender. The resulting suspension was allowed to stand for 10 minutes and the pH was determined using a digital pH meter.

**Swelling Power**

The swelling capacity was determined by the method of Okaka and Potter (1977). A 100-mL graduated cylinder was filled with the sample to the 10-mL mark. Distilled water was added to give a total volume of 50 mL. The top of the graduated cylinder was tightly covered and the suspension was mixed by inverting the cylinder. The suspension was inverted again after two minutes and was left to stand for eight minutes after which the volume occupied by the sample was measured.

**Water Absorption Capacity**

Water Absorption Capacity was determined using the method of Adeleke and Odedeji (2010). 15mL of distilled water was added to one gram of flour in a pre-weighed 25 mL centrifuge tube. It was mixed for two minutes using a vortex mixer and centrifuged at 4000 rpm for 20 minutes. The supernatant was discarded and the centrifuge tube was weighed again. The water absorption capacity was expressed as the weight of water bound by one gram dried flour and calculated using the equation:

\[ WAC(\%) = \frac{W_f - W_i}{W_f} \times 100 \quad (2) \]

where:

\[ W_i = \text{weight (g) of dried sample} \]
\[ W_f = \text{weight (g) of final sample} \]

**Oil Absorption Capacity**

Oil Absorption Capacity was determined using the method of Adeleke and Odedeji (2010). Ten milliliters of refined corn oil was added to one gram of flour in a 50-mL centrifuge tube. It was mixed for two minutes using a vortex mixer and centrifuged at 4000 rpm for 20 minutes. The volume of free oil was recorded before being decanted. Fat absorption capacity was expressed as mL of oil bound by one gram dried flour and calculated using the equation:

\[ OAC(\%) = \frac{W_1 - W_2}{W_0} \times 100 \quad (3) \]

where:

\[ W_0 = \text{weight (g) of dried sample} \]
\[ W_1 = \text{weight (g) of oil added} \]
\[ W_2 = \text{weight (g) of final sample} \]

**Emulsification Capacity and Stability**

Emulsion capacity and stability were determined by the method of Yasumatsu et al. (1972) as described by Chandra and Samsher (2013). The emulsion containing one gram sample, 10 mL distilled water and 10 mL soya oil was placed in a centrifuge tube and centrifuged at 2000 rpm at room temperature for 15 minutes. The ratio of the height of emulsion layer to the total height of the mixture was calculated as percent emulsion capacity. The centrifuge tubes containing the emulsion were heated at 80°C for 30 minutes in a water bath, cooled for 15 minutes under running tap water and then centrifuged at 2000 rpm for 15 minutes. Emulsion stability was expressed as percentage of the ratio of the height of emulsion layer to the total height of the mixture.

**Foaming Capacity and Stability**

Foaming capacity and stability were determined using the method of Chandra
and Samsher (2013). One gram of flour sample and 50 mL distilled water heated at 30°C was placed in a graduated cylinder. It was shaken for five minutes to form a foam layer. The volume of the foam after shaking was expressed as foaming capacity and calculated using the following equations 4 and 5.

**Foaming capacity (%)**

\[
(4) \text{Foaming capacity(\%)} = \frac{\text{Foam volume after shaking} - \text{Volume before shaking}}{\text{Volume before shaking}} \times 100
\]

\[
(5) \text{Foaming capacity(\%)} = \frac{\text{Foam volume after 1h}}{\text{Initial Foam volume after 30 secs}} \times 100
\]

**Gelation Capacity**

2% to 20% suspension with 5 mL distilled water was prepared in a test tube. It was heated for one hour in a boiling water bath, rapidly cooled under running tap water and cooled again at 4°C for 2 hours. The test tube was inverted to see if the content fell or slipped off. The least concentration where the contents did not fall off is the least gelation concentration (Adeleke & Odedeji, 2010).

**Bulk Density**

Packed and loose bulk density were determined using the method of Adeleke and Odedeji (2010). A fifty gram flour sample was placed in a 100 mL graduated cylinder. The cylinder was tapped several times on a laboratory bench to constant volume. The volume of the sample was recorded and the packed bulk density was determined using equation 6.

For the loose bulk density, the same procedure was followed but no tapping was done.

**Viscosity**

Flour samples were sent to Grain Quality and Nutrition Services Laboratory of the International Rice Research Institute (IRRI) at Los Baños, Laguna, Philippines. Viscosity was determined using the Rapid Visco Analyzer.

**Amylose Content**

Flour samples were sent to Grain Quality and Nutrition Services Laboratory of the International Rice Research Institute (IRRI) at Los Baños, Laguna, Philippines for amylose content determination using the colorimetric assay of amylose-iodine complex.

**Experimental Design**

The experimental design used in this study was the Completely Randomized Design (CRD) with three replicates for each parameter, except for viscosity and amylose content. The treatments were the flour derived from three sweet potato varieties, namely, VSP-6, PSB SP-17, and NSIC SP-31.

**Statistical Analysis**

The data were statistically analyzed using One-way Analysis of Variance (ANOVA) with Tukey’s HSD test for pair-wise comparison of means.

**Results and Discussion**

**Functional Properties**

Functional properties determine the application and use of the food material for various food products. The functional properties of the flour samples prepared from NSIC SP-32 (NSIC SP-32), PSB SP-17 (F2), and VSP-6 (F3) are shown.
in Table 1. These functional properties reflect the complex interaction between the composition, structure, molecular conformation, and physicochemical properties of food components together with the nature of the environment in which these are associated and measured (Chandra & Samsher, 2013).

**Moisture Content**

Table 1 shows that VSP-6 contains the least moisture (9.2185%) which differs significantly from that of NSIC SP-32 (10.2300%) and PSB SP-17 (10.4424%). However, all the values are less than the 14% flour moisture specification which is the acceptable limit for dry products (Adeleke & Odedeji, 2010). This suggests high storage life of the sweet potato flour as values less than 14% are relatively stable at room temperature. Higher values would promote the growth of microorganisms that are naturally present in the flour which would lead to undesirable odor and flavor. Low moisture content of the flour also prevents mold growth and reduces moisture dependent biochemical reactions (Akubor et al., 2013).

**pH**

The pH of the three different sweet potato flours ranged from 5.4-5.8 (Table 1). Even though statistical analysis shows that the values are significantly different from each other, these values still agree with the pH of 5.6 reported of sweet potato flour studied by Adeleke and Odedeji (2010). This pH value tends to lean towards acidity wherein these types of flour can be useful in the formulation of acidic food like protein-rich carbonated beverages (Kinsella, 1979; Adebowale et al., 2005). According to United States Department of Agriculture (USDA, 2012), sweet potatoes generally contain 37% Vitamin C. The presence of ascorbic acid at different levels per variety might be the reason why sweet potato flours are slightly acidic. Also, acidic products tend to have a longer shelf-life compared to less acidic counterparts (Adeleke & Odedeji, 2010). This is because most bacteria that contribute to food spoilage do not grow in acidic conditions. Example of these acidic food products are pickled foods which are made shelf stable by the addition of some type of acidifying agent, such as lemon juice or vinegar. According to Smith and Stratton (2007), a pH of 4.6 or lower will not support the growth of Clostridium botulinum in food preservation for longer shelf-life of product.

**Swelling Power**

Swelling power is a measure of the flour’s hydration capacity. Among the three flour samples, VSP-6 appears to have a significantly different and largest swelling power of 103.3% compared to NSIC SP-32 and PSB SP-17 having 66.7% and 70.3% respectively (Table 1). The values obtained in this study are greater than the reported 50% swelling power of sweet potato studied by Adeleke & Odedeji (2010). Nevertheless, Chandra and Samsher (2013) pointed out that the swelling capacity of flour depends on size of particles, variety and types of processing methods or unit operations. Moreover, swelling power is an indication of the water absorption index of the granules when heated (Loos et al., 1981). According to Avula (2005), swelling power also provides evidence of bonding between starch molecules. The swelling power of starch depends on the water-holding capacity of starch molecules by hydrogen bonding (Lee & Osman, 1991). In a gelatinization study, it was found out that hydrogen bonds stabilizing the structure of the double helices in crystallites are broken during gelatinization and are replaced by hydrogen bonds with water, and swelling is regulated.
Table 1. Functional properties of flour from different sweet potato (*Ipomoea batatas* L.) varieties

<table>
<thead>
<tr>
<th>Functional Property</th>
<th>NSIC SP-32 (Mean ± SD)</th>
<th>PSB SP-17 (Mean ± SD)</th>
<th>VSP-6 (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture Content (%)</td>
<td>10.230 ± 0.328</td>
<td>10.442 ± 0.286</td>
<td>9.218 ± 0.220</td>
</tr>
<tr>
<td>pH</td>
<td>5.53 ± 0.011</td>
<td>5.44 ± 0.01</td>
<td>5.78 ± 0.07</td>
</tr>
<tr>
<td>Swelling Power (%)</td>
<td>66.7 ± 5.8</td>
<td>70.3 ± 5.5</td>
<td>103.3 ± 5.8</td>
</tr>
<tr>
<td>Water Capacity (mL/g)</td>
<td>2.41 ± 0.21</td>
<td>3.22 ± 0.36</td>
<td>2.80 ± 0.67</td>
</tr>
<tr>
<td>Oil Absorption Capacity (mL/g)</td>
<td>0.55 ± 0.12</td>
<td>0.74 ± 0.22</td>
<td>1.12 ± 0.30</td>
</tr>
<tr>
<td>Emulsification Capacity (%)</td>
<td>28.00 ± 1.61</td>
<td>32.60 ± 1.52</td>
<td>26.60 ± 0.63</td>
</tr>
<tr>
<td>Emulsification Stability (%)</td>
<td>24.00 ± 0.34</td>
<td>32.60 ± 1.60</td>
<td>26.60 ± 2.50</td>
</tr>
<tr>
<td>Foaming Capacity (%)</td>
<td>5.8 ± 0.70</td>
<td>5.8 ± 0.31</td>
<td>8.3 ± 0.40</td>
</tr>
<tr>
<td>Foaming Stability (%)</td>
<td>25.70 ± 4.99</td>
<td>60.90 ± 4.65</td>
<td>64.90 ± 5.06</td>
</tr>
<tr>
<td>Gelation Capacity (%)</td>
<td>7.07 ± 0.23</td>
<td>6.80 ± 0.4</td>
<td>9.33 ± 0.23</td>
</tr>
<tr>
<td>Loose Bulk Density (g/mL)</td>
<td>0.40 ± 0.003</td>
<td>0.37 ± 0.006</td>
<td>0.49 ± 0.006</td>
</tr>
<tr>
<td>Packed Bulk Density (g/mL)</td>
<td>0.63 ± 0.01</td>
<td>0.61 ± 0.01</td>
<td>0.70 ± 0.01</td>
</tr>
<tr>
<td>Viscosity* (cP)</td>
<td>3077</td>
<td>3536</td>
<td>2653</td>
</tr>
</tbody>
</table>

*Mean ± SD of 3 replicates

Different superscripts within a row are significantly different at P < 0.05

*peak viscosity values from IRRI, Los Baños, Laguna RVA analysis

by the crystallinity of the starch (Tester & Karkalas; Sasaki & Matsuki, 1998).

**Water Absorption Capacity**

PSB SP-17 had the highest water absorption capacity (3.2201 g/cm³) while NSIC SP-32 had the lowest (2.4101 g/cm³) (Table 1). However, statistical analysis revealed that these values are not significantly different from each other. According to Chandra and Samsher (2013), high water absorption capacity could be attributed to the presence of high amount of starch and fiber in the flour. In addition, the extent of protein hydration which correlates strongly with the content of polar residues in the flour as well as the interaction between water molecules and hydrophilic groups which occurs via hydrogen bonding, may have contributed to high absorption capacity. However, water absorption of flour is also affected to some extent by pH and nature of the protein (Gordon, 1993; Akubor et al., 2013). This might be the reason of the inconsistent results or trend on the swelling power of sweet potato flour studied which also relies on the hydrogen bonding in the starch present. Flour with good water absorption capacity gives advantage in applications such as thickener in liquid, semi-liquid foods, good binder to provide consistency in food preparations such as semi-solid beverages, soups, dough and baked products (Adeyeye & Aye, 1998).

**Oil Absorption Capacity**

Table 1 shows that VSP-6 flour exhibited a significantly higher oil absorption capacity (1.1216 mL/cm³) compared to NSIC SP-32 flour (0.5533 mL/cm³). However, no significant difference was observed between the oil absorption capacity of PSB SP-17 (0.7428 mL/cm³) with those of the other sweet
potato flour samples. The major chemical component affecting oil absorption capacity is protein, which involves both hydrophilic and hydrophobic amino acid residues. High hydrophobic amino acid residue in the protein will give high oil absorption capacity. The mechanism of this property is attributed to the physical entrapment of oil and the binding of fat to the non-polar chains of the protein by capillary action (Wang & Kinsella, 1976). This characteristic is important in flavor retention, structural interaction, and mouth feel of food products upon application.

Emulsification Capacity and Stability

Emulsification capacity ranged between 26%-32% in the three flour samples with PSB SP-17 having the highest value (32.6%) which differs significantly from the other sweet potato flour samples (Table 1). Furthermore, the emulsification capacity of sweet potato flour in this study is comparable with the 25.40% emulsification capacity reported by Adeleke and Odedeji (2010) for sweet potato flour. According to Chandra and Samsher (2013), the emulsification capacity of the flour could be attributed to the hydrophobicity of the proteins present as well as the fat–binding property. Moreover, Adebowale et al. (2005) stated that changes in the value of this property are influenced by many factors among which are solubility, pH and concentration. It may also be related to the type of protein present. Soluble proteins are surface active and promote formation of oil-in-water emulsion (Akubor et al., 2013). Emulsification stability values are similar to the emulsion capacity values except for NSIC SP-32 having an emulsification capacity and stability of 28.0% and 24.0%, respectively. This implies that the emulsion formed in PSB SP-17 and VSP-6 can be deemed stable. An emulsion is an unstable colloid and thus need energy input in the system through shaking, stirring, homogenizing, or spraying to form stable emulsion (Atta & El-Shenawi, 2013). Heating was done in this study to determine the emulsion stability. Flour with good emulsion activity can be used in meat products like sausages and in stabilizing colloidal food systems.

Foaming Capacity and Stability

VSP-6 had the highest and significantly different foaming capacity of 8.3% among the flour samples while NSIC SP-32 and PSB SP-17 had the same values of 5.8% (Table 1). These values are greater compared to the reported sweet potato foaming capacity of 1.28% by Adeleke & Odedeji (2010). This functional property depends on the type of protein the flour contains. This may somehow indicate that this flour from certain sweet potato varieties contains proteins which have more flexible random coiled structure that reduce surface tension compared to the globular proteins. The formation of protein-based foams involves the diffusion of soluble proteins toward the air-water interface and rapid conformational change and rearrangement at the interface (Wang et al., 1999). PSB SP-17 and VSP-6 had high foam stability of 60.9% and 64.9%, respectively (Table 2). The proteins present might be more flexible because of the loss of complex secondary or tertiary structure, which is due to the loss of phytate, mineral, and cellular components (Wang et al., 1999). On the other hand, low foam stability in NSIC SP-32 indicates the lack of formation of a thick, cohesive, and viscoelastic film around gas bubbles that will prevent the foams from collapsing. Foams are used to improve texture, consistency and appearance of foods (Akubor & Eze, 2012). PSB SP-17 and VSP-6 may find applications in baked and confectionery products.

Gelation Capacity

Gelation is an aggregation of denatured molecules. NSIC SP-32 and PSB SP-17 have the gelation capacity at the lowest
values around 7% flour concentration which is significantly different from VSP-6 with a value of 9%. Gelation capacities at low concentration levels depict a high concentration of protein (Adebowale et al., 2005). Gelation capacities are also interrelated to water absorption capacity. According to Khalid and Elharadallou (2013), low water absorption can explain a deficient gelation formation capacity. However, this can be affected by ratios of different constituent proteins, lipids and carbohydrate present in the flour (Fasasi et al., 2006) as well as the interactions between them. This may have affected the results as supported by the water absorption capacity which also showed no significant difference among values. In food application, flour with low value of gelation concentration can be a good thickening agent (Akubor et al., 2013) and would be useful in food systems such as puddings and snacks which require thickening and gelling.

**Bulk Density**

VSP-6 had the highest loose and packed bulk density (0.50 g/mL and 0.70 g/mL, respectively) while PSB SP-17 had the lowest values (0.37 g/mL and 0.61 g/mL, respectively) (Table 1). All values between flour samples differ significantly. The difference in the particle size and initial moisture content affects the variations in bulk density of flour (Chandra & Samsher, 2013). Bulk density is very important in determining the packaging requirement, material handling and application in wet processing in the food industry (Adeleke & Odedeji, 2010).

**Viscosity**

Viscosity is the most commonly used parameter to define a particular sample’s quality. Peak viscosity is often correlated with final product quality and provides an indication of the viscous load likely to be encountered by a mixing cooker. (Perten Instruments, 2012). Table 1 shows that PSB SP-17 had the highest viscosity (3536 cP) followed by NSIC SP-32 (3077 cP) and VSP-6 (2653 cP). These values are comparable with the reported viscosity values of 2500 cP for pancake syrup and 3100 cP for maple syrup (Hydramotion, 2005). According to Adeleke & Odedeji (2010), this property is affected by the gluten content of sweet potato flour. It was further reported that sweet potato flour has a viscosity of 271.08 RVU (Rapid Visco Unit) or 3252.96 cP which is somehow similar to the values obtained in this study. High viscosity means high gluten present in the flour. According to Nabubuya et al. (2012), peak viscosity of flour is reported to correlate negatively with the amylose content of the starch in flour.

**Amylose Content**

Table 2 shows the amylose content of flour from three sweet potato varieties. Zaidul et al. (2007), reported that the lower amylose content is associated with a higher peak viscosity of sweet potato starch and very small differences between the peak and final viscosities. They also reported that sweet potato starch has an amylose content of 23.4% comparable to the values obtained in this study. VSP-6 had the highest amylose content of 25.5% and the lowest viscosity of 2653 cP (Table 1). Meanwhile, PSB SP-17 with the lowest amylose content of 23.4% had the highest viscosity of 3536 cP.

Based on the results, the three flours have shown significant differences in their functional properties as they have been produced from different varieties of sweet potato. However, it is recommended to conduct further study to confirm the findings of functional properties and to use a flour rheology instrument to validate the methods used in the study. Protein and carbohydrate content of the flour samples should be also be measured. The functional properties of other recommended varieties of sweet potato should be studied and actual food application experiments are recommended to test and
Table 2. Amylose Content (%) of flour from different sweetpotato ( Ipomoea batatas L.) varieties

<table>
<thead>
<tr>
<th>Sweetpotato Flour</th>
<th>Amylose Content* (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSIC SP-32</td>
<td>25.1</td>
</tr>
<tr>
<td>PSB SP-17</td>
<td>23.4</td>
</tr>
<tr>
<td>VSP-6</td>
<td>25.5</td>
</tr>
</tbody>
</table>

*amylose content values from IRRI, Los Baños, Laguna

assess the results in the study in comparison with the commercially available wheat flour. Flour blends of different levels of substitution with sweet potato flour should be pursued to enhance the functional properties for better efficiency in food applications.

Conclusion

All the flour samples show great potential in the characteristics (moisture content and pH) of long shelf life for food materials. PSB SP-17 has the highest potential in the applications of thickening, binding and gelling in food processing compared to the other two sweet potato flour samples, as supported by the high water absorption capacity and its low gelation capacity. Furthermore, PSB SP-17 flour exhibited good fat-binding ability for applications in meat processing and in colloidal food systems. It also showed the highest viscosity. Although NSIC SP-32 had these characteristics, it only came second to PSB SP-17. VSP-6 showed the highest bulk density, foaming capacity and amylose content which is of good use in food preparations.

References Cited


